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A color photometer for calibrating light sources

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for calibrating light sources

ABSTRACT

A Color Photometer designed to calibrate tungsten sources to a standard source has been produced. It is accurate to within a few mired values, though not enough testing was done to specify its limits. There is also a good probability that the color photometer can be used to find the color temperature of most tungsten sources including many that are not close to the color temperature of the standard source.

By designing and building a simple device for measuring color temperature, and intensity, two goals can be achieved. One is that unknown light sources can be calibrated for use in other experiments. The second is the use of the device for demonstration and teaching. The device ~~will~~ makes use of photo cells and an integrating sphere.

INTRODUCTION

Color temperature is a "measurement" that is convenient for describing the color quality of a light source. It is a relative measure which compares the visual appearance of the light radiated by a theoretically perfect radiator, or blackbody when heated to incandescence, to other light sources. When a light source visually matches the color of the blackbody radiator, the light source is said to have a color temperature corresponding to the actual temperature of the blackbody expressed in degrees Kelvin.

no!

Not exactly correct

Since color temperature refers only to the visual appearance of a light source, a lamp may not actually emit a smooth spectral distribution as implied by "color temperature". Flourescent lamps, for example do not have a continuous, smooth spectral-distribution curve that is characteristic of a tungsten-filament source.

Since ~~the assumption that~~ tungsten sources are similar to a Blackbody, only two colors have to be used in comparison of sources.

The inverse square law states:

$$I = \lim (ED^2)$$

Where E = illumina~~tion,~~ nce which is equal to the luminous flux falling on the surface per unit area. At small distances from the source, ED^2 values vary a great deal, but at larger distances, ED^2 becomes a constant. To measure (I) the inverse square law can be used with a Receiving surface of known area. ~~The use of~~ A a photo cell as the reciever can then be used to detect the light, and changes of (E). By using a lamp of known out-put. the out-put of an unknown lamp can be calculated by comparing the distances between tre sources and the detector when they both produce the same ~~change in~~ response of the detector. The use of a cell, which closely approximates the visiblity curve enables the measurement of color temperature, as well. It is necessary for two detectors to be exposed to the same quality and quantity of light, but through two different colors of filters. Since the spectral responsse of photo cells varies with intensity, the intensity during comparisons must be held constant. This can be done by taking a white light reading in addition to the colored readings. It is also important to be sure that all the photo cells

?

No!

?

This is probably more dependent on intensity!

Not a necessary condition

receive Identical amounts of light. This can be attained by the use of an integrating-sphere because the illumination at every point on the wall of the sphere is the same, and is directly proportional to the total flux entering the sphere.

DESIGN

In searching for a suitable sphere, a plastic sphere 5.5 inches in diameter was obtained from a container of bath powder. Because the sphere was translucint , an opauque silver paint was applied to both the inner and outer surfaces.

For an integrating-sphere to function the inner surface must not only be highly reflecting, but it must also be a Lambertian diffuser. The International commission on Illumination (CIE) used to have as the standard reflectance material freshly-smoked magnesium oxide (MgO), in a layer thick enough to be opaque. Now the standard has been redefined so that I used the Eastman White Reflectance Paint to cover the inner surface of the sphere. "Eastman White Reflectance Paint is a composition of barium sulfate, binder and solvent specially prepared to form coatings with spectral reflectance higher than magnesium oxide throughout the ultraviolet, visible, and part of the near-infrared regions of the spectrum. It is characterized by high stability and nearly perfect diffuse reflection. "[1] "The remarkably high diffuse reflectance of light over a very broad spectral range proveded by this coating, coupled with its unusual stability against atmospheric conditions and high intensity radiation, makes possible increased sensitivity of existing instruments and provides such benefits as increased accuracy of color measurement."[2] "The reflectance of Eastman White Reflectance Paint coatings is higher than freshly prepared magnesium oxide coatings as indicated in figure 1. This difference widens as magnesium oxide ages, because the reflectance os smoked magnesium oxide coatings decreases rapidly on exposure to the atmosphere (See Figure 2), while Eastman White Reflectance Paint coatings are stable."[3]

The circuitry used in the color photometer is of simple and basic design. It is a simple Wheatstone Bridge used to measure resistance or to show a difference in resistance.

1,2,&3 Eastman Kodak Company; KODAK Publication No. JJ-32

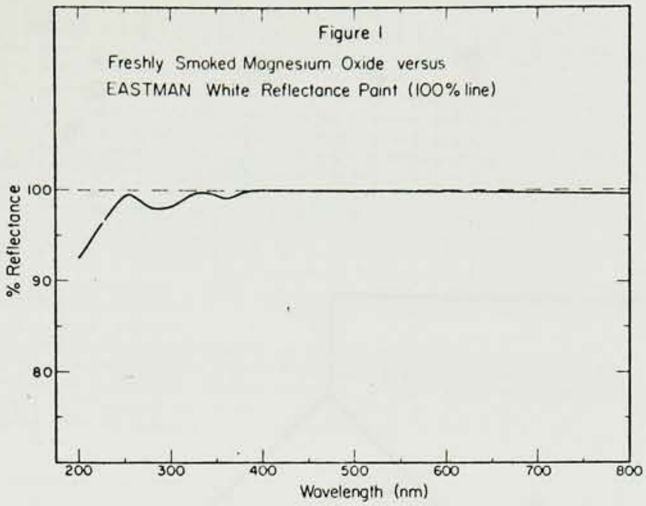


Figure 1
Freshly Smoked Magnesium Oxide versus
EASTMAN White Reflectance Paint (100% line)
% Reflectance
100
90
80
200
300
400
500
600
700
800
Wavelength (nm)

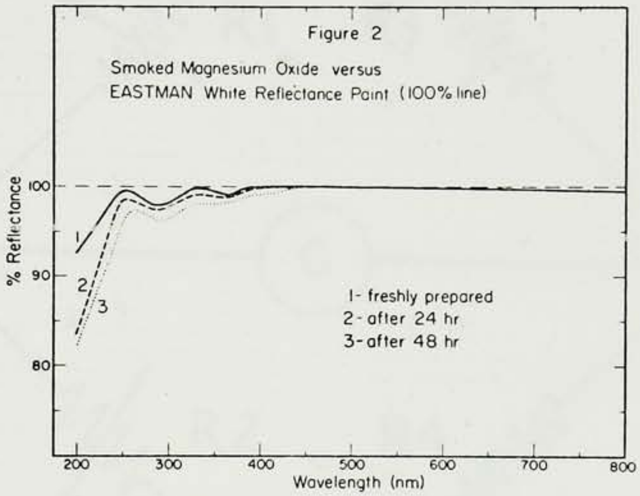


Figure 2
Smoked Magnesium Oxide versus
EASTMAN White Reflectance Paint (100% line)
% Reflectance
100
90
80
1
2
3
1- freshly prepared
2- after 24 hr
3- after 48 hr
200
300
400
500
600
700
800
Wavelength (nm)

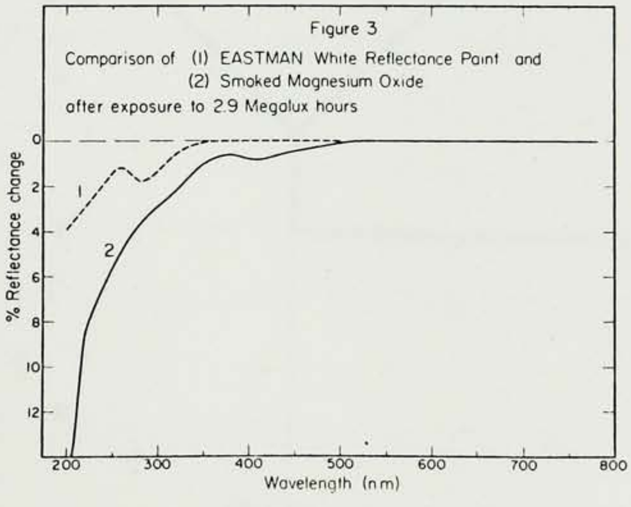


Figure 3
Comparison of (1) EASTMAN White Reflectance Paint and
(2) Smoked Magnesium Oxide
after exposure to 2.9 Megalux hours
% Reflectance change
0
2
4
6
8
10
12
1
2
200
300
400
500
600
700
800
Wavelength (nm)

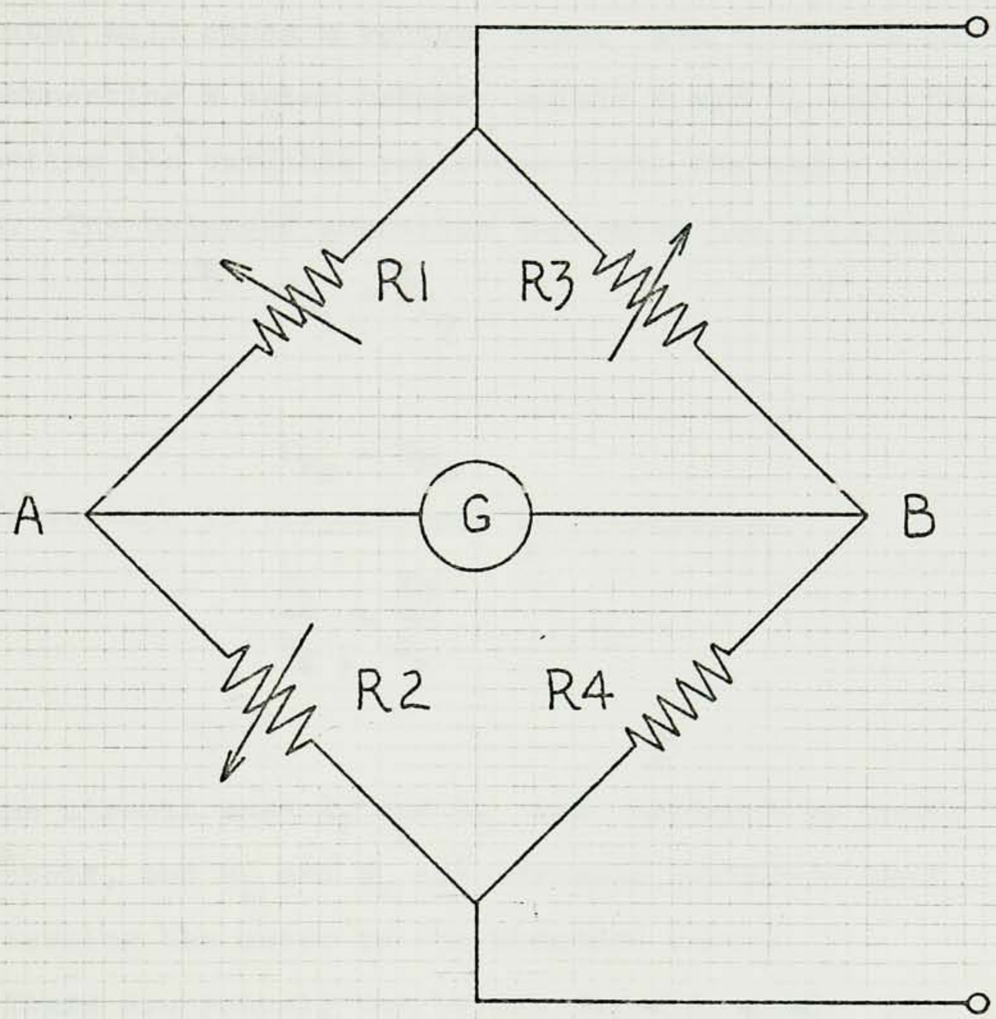


FIG. 4

Figure 4 is the schematic diagram. R_1 , R_2 , and R_3 are precision resistors. R_x is the unknown. When voltage is applied to the circuit, current will flow through the branch R_1R_2 and parallel branch R_3R_x. Each resistor will cause a voltage drop. The bridge is balanced by connecting a meter between points A and B, and then adjusting the variable resistors until the meter read zero. The balanced condition indicates the following:

$$E_{R_1} = E_{R_3}$$

and

$$E_{R_2} = E_{R_x}$$

Since voltage is proportional to resistance,

$$\frac{R_1}{R_2} = \frac{R_3}{R_x}$$

In the circuit used R_1 and R_3 are replaced by photo resistors, and R_2 and R_x are variable resistors used for zeroing the meter to the Standard source.

There are actualy two bridge circuits used. One has two photo cells for color reading using a 25 filter over one and a 48A filter over the other. The second circuit has only one photo cell which is used for a white light intensity reading. The schematic of the complete circuit is on the following page.

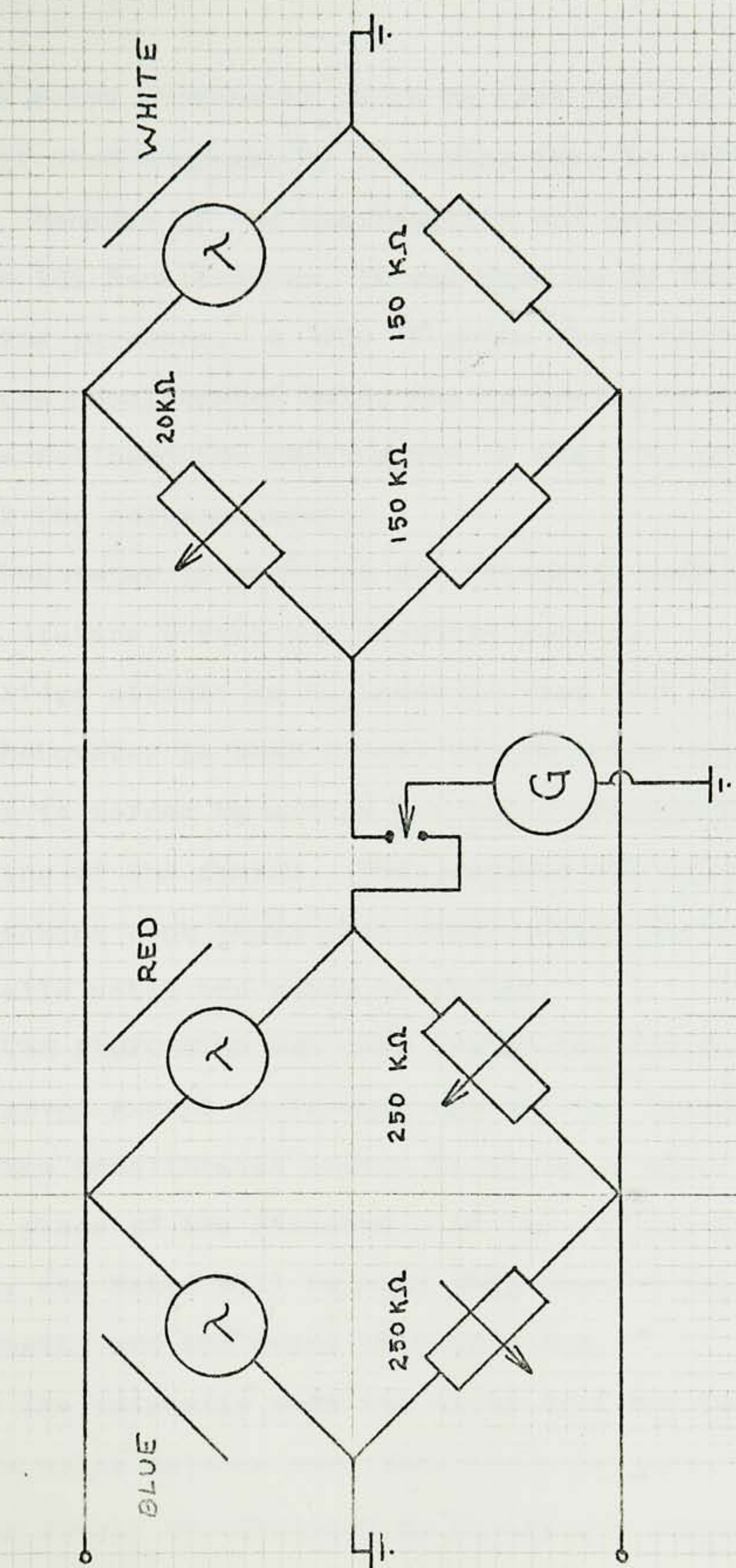


FIG. 5

USE

This color photometer is to be used for the calibration of uncalibrated sources, by comparing them to calibrated sources. Because of the availability and accuracy of the Kodak 101 Sensitometer, it was used as my "standard" for testing purposes. A 3200 °K photo flood bulb was used as the uncalibrated bulb. The following is the precedure followed for testing and is also the procedure for using the colorphotometer.

1) The Photometer is place in the intensity mode and placed a distant D from the Standard source.

2) the bridge circuit is adjusted to read zero at distance D.

3) The photometer is then placed in the color mode, and the meter is zeroed by moving the color probe across the opening of the sphere. This adjusts the amount of light reaching each photo cell which varies the resistance of the cells until the meter is zeroed.

4) ONCE THE PHOTOMETER HAS BEEN ZEROED the controlls are not moved except to re-zero against the Standard.

5) Next the uncalibrated source is place on theoptical bench in place of the Standard. If the two sources are the same, the Meter will be zero at distance D for both the intensity and the color balance modes.

6) If in the intensity mode the meter does not read zero, the color balance mode should not be used. The intensity should be equalized by moving the uncalibrated source towards or away from the photometer head until

the meter zeros. If the meter remains zeroed in the color mode , the uncalibrated source can then be said to have the same color temperature as the standard and the luminous out put can be calculated using the Inverse Square Law.

EXPERIMENTAL Results

To test the color Photometer a Kodak 101 Sensitometer was compared to a photo flood of 3200^0K. When the photo flood was placed so that the intensity mode indicated zero the color mode was not zeroed, indicating the two sources were not the same. Using the Mired value system, the filters needed to change the photo flood to a 2850^oK source was calculated. The filters used were(81c + 82A + 81B + 82). Using this combination of filters, the photometer was placed in the intensity mode and the meter zeroed by moving the photo Flood. When the photometer was switched to the color mode the meter remained zeroed indicating that the color temperature was 2850^oK as predicted.

Further experimentation showed that a Mired shift of only a few (±6) values was easily detected though an accurated number can not be given due to lack of data.

DISCUSSION

Each color temperature can have an assigned "Mired" value(MIcroREciprocal DEgrees).[4]

$$\text{Mired value} = \frac{1,000,000}{\text{color temperature in degrees Kelvin}}$$

Photographic filters can be used to modify the effective color temperature of a light source, which means the mired valure a light source may have, can be controlled. The filters can be given a "mired shift value," represented by:

$$10^6 / T_2 - 10^6 / T_1$$

where T_1 = color temperature of the original source

T_2 = color temperature through the filter

From this follows:

$$T_2 = T_1 10^6 / 10^6 + MT_1$$

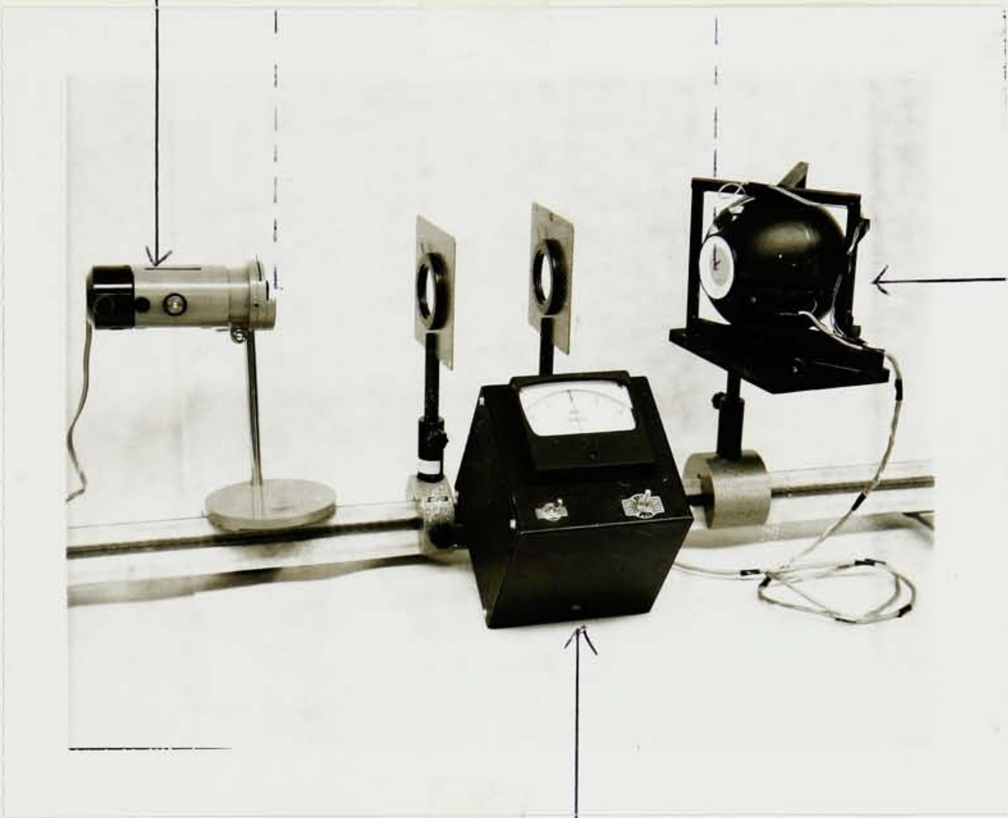
where M = mired value or mired value of the filter used

Thus the Kodak "mired nomograph for light source conversion", can be used in conjunction with the color photometer for determination of color temperature of most tungsten sources.

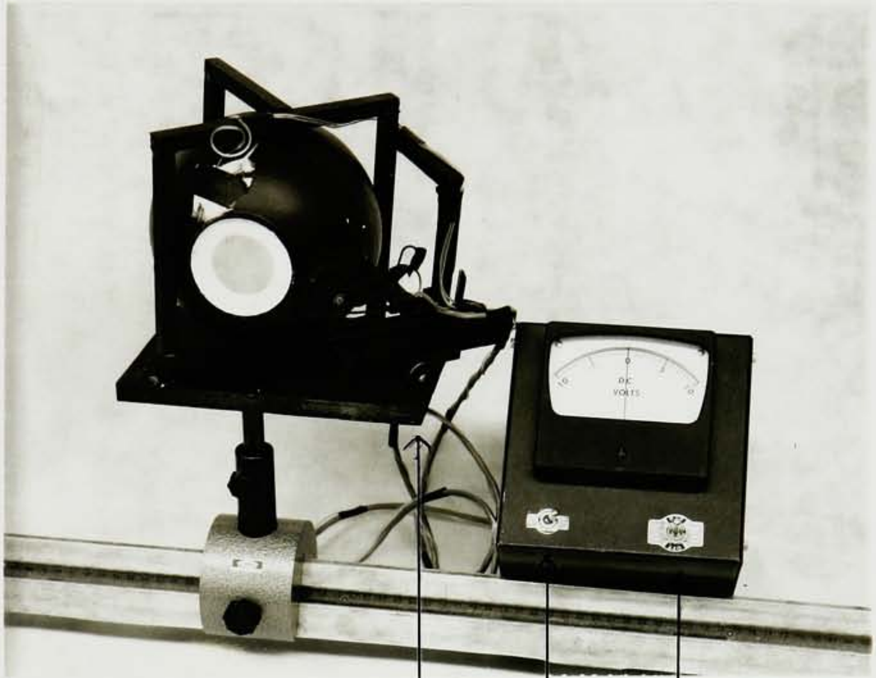
Use of the color photometer would be very simple. First the meter would be zeroed as described earlier. Next the unknown source is positioned so that the meter is zeroed in the intensity mode. When the photometer is switched to the color mode a deflection of the meter to the right or to the left would indicate a plus or minus mired shift was still needed, then filters would be placed infront of the photometer head and the precedure repeated until the meter remained zero in both modes. Now the mired shift value could be used to determine the color temperature .

RECOMMENDATIONS

Using the ideas in the DISCUSSICN, I sugest making astpped filter or continuous filter of +400 to-400 mired value shift for use with the color photometer.



Source
D
Photometer Head
Photometer



ON-OFF

MODE [Right - Intensity
Left - Color]

COLOR BALANCER

ENTRANCE
window

COLOR
BALANCER